

# SCIENCE FOR CERAMIC PRODUCTION

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## SURFACE ROUGHNESS OF ELEMENTARY ALUMINUM OXIDE FILAMENTS

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The surface roughness of elementary aluminum oxide filaments is determined. The roughness of filament-drawing parts of textile machines in textile processing of complex aluminum oxide filaments is substantiated. The height of the profile irregularities at ten points, the standard deviation of the profile and average value of the surface roughness parameter are determined.

**Key words:** elementary aluminum oxide filaments, surface roughness, atomic force microscopy.

Fibers and filaments based on aluminum oxide comprise the main group of “ceramic” oxide fibers. Among refractory oxides — calcium, magnesium, aluminum, beryllium, zirconium, hafnium, thorium and others as well as many mixed oxides, only aluminum oxide fibers and filaments are manufactured commercially [1].

In the Russian Federation, the production of filaments and articles from aluminum oxide for technical use is at the experimental stage [2].

While working to develop a technology for textile processing of aluminum oxide based complex fibers consisting of 80 elementary filaments we found that there is no information on the morphology and state of the surface of elementary filaments, specifically, the surface-roughness parameters.

Friction and wear during contact of filaments with filament-drawing parts of machines are largely due to the roughness of the friction pair filament – filament-drawing part.

The character of the interaction of filaments and filament-drawing working organs is studied in a number of works [3 – 4]. It has been established that the wear of working organs by different textile fibers is abrasive.

The wear of rubbing surfaces and failure due to corrosion, erosion and cavitation occur on the surface of parts and in a layer adjoining the surface.

Surface quality is one of the most important factors securing high performance of the filament-drawing parts (FDP) of textile machines. Imparting special properties to the surfaces of parts considerably improves the processing of textile materials.

The relation between the properties of a worked surface and the performance of FDP (friction and wear during slipping and rocking and so forth) has been studied adequately.

Surface roughness is one of the main geometric characteristics of FDP surfaces and affects product quality.

The objective of the present work is to substantiate the choice of the roughness of the filament-drawing parts of textile machines processing complex aluminum oxide based filaments.

The principal roughness parameters are [5]:

1) the height  $Rz$  of the profile irregularities at ten points (ten-point height), where  $Rz$  is the sum of the average absolute values of the height at the five highest profile peaks  $y_{pi}$  and depth of the five deepest profile valleys  $y_{vi}$  within the base length  $l$ :

$$Rz = \frac{\sum_{i=1}^5 |y_{pi}| + \sum_{i=1}^5 |y_{vi}|}{5},$$

where  $y_{pi}$  is the height of the  $i$ th highest peak of the profile  $i = 1, \dots, 5$ ;  $y_{vi}$  is the depth of the  $i$ th deepest valley of the profile  $i = 1, \dots, 5$ ;

2) the standard deviation of the profile  $Rq$  (root mean square) — the root-mean-square deviation of the profile along the  $y$  axis within a baseline of length  $l$ :

$$Rq = \sqrt{\frac{1}{l} \int_0^l y^2(x) dx},$$

the larger  $Rq$ , the rougher the surface is;

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3) the average value of the surface-roughness parameter  $\bar{P}$  determined on all lengths of the roughness estimate:

$$\bar{P} = \frac{1}{k} \sum_{i=1}^k \frac{1}{n} \sum_{j=1}^n R_j,$$

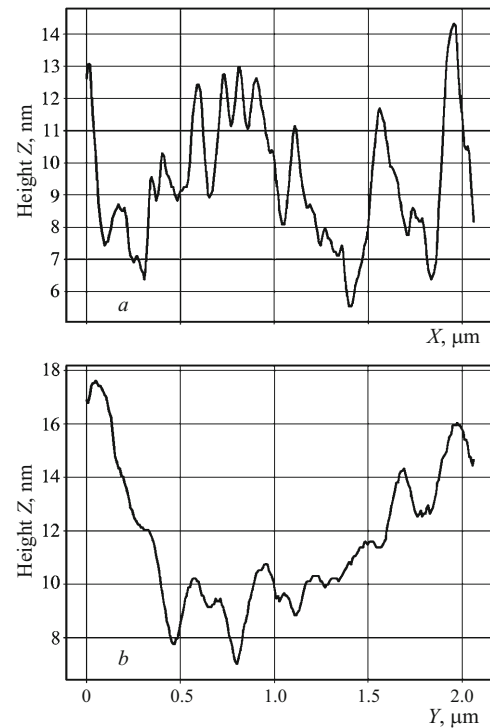
where  $k$  is the number of unit lengths of the estimate;  $R_j$  is the value of the parameter determined on a single base length; and,  $n$  is the number of base lengths per unit length of the estimate.

In the present work, the surface-roughness parameters  $Rz$  and  $Rq$  were used to evaluate the surface roughness of elementary filaments as one component of the friction pair filament – filament-drawing part.

A Ntegra Prima atomic-force microscope (NT-MDT) was used to study the surface. Despite many difficulties (delivery of the probe to the sample, size of an elementary filament, and so forth), the studies were performed mainly in the contact working regime using CSG01 probe sensors with the following parameters: size  $3.4 \times 1.6 \times 0.3$  mm, needle-tip radius 10 nm and stiffness 0.03 N/m. This made it possible to prevent the capillary and adhesion forces as well as different kinds of contaminants from affecting the final value of the surface-roughness parameter. To prevent an elementary aluminum oxide based filament from shifting special arms were used to firmly secure the sample to a substrate; scanning was conducted with frequency 0.4 Hz [6].

The IMAGE ANALISIS code was used to process the results. This code makes it possible to determine the roughness of an experimental sample in accordance with the ISO 4287-1:1984 standard. Three images of the surface of elementary aluminum oxide filaments were processed.

The values of the roughness parameters  $Rz$  and  $Rq$  were determined in sections parallel to the  $X$  and  $Y$  axes. Twelve



**Fig. 1.** Profile of surface peaks of an elementary aluminum oxide filament (line 125; see Table 1) along the  $X$  and  $Y$  axes.

sections were studied. The spacing between the sections depended on the sizes of the image of a section of an elementary filament.

The values of the roughness parameters and image sizes are presented in Table 1.

According to the data obtained the height of the profile peaks at ten points (ten-point height)  $Rz$  ranges from 0.015 to 0.0055  $\mu\text{m}$ . The standard (root-mean-square) deviation of the

**TABLE 1.** Values of the Surface Parameter and Image Size

Line No.	Image No. 1 2000 × 2000 nm				Image No. 2 1050 × 1050 nm				Image No. 3 1500 × 1500 nm			
	Roughness parameter, nm				Roughness parameter, nm				Roughness parameter, nm			
	$Rz$	$Rq$	$Rz$	$Rq$	$Rz$	$Rq$	$Rz$	$Rq$	$Rz$	$Rq$	$Rz$	$Rq$
0	9.49	10.43	12.37	12.99	5.79	5.48	7.83	7.30	13.60	11.71	32.53	32.37
25	9.88	10.21	8.83	9.05	5.09	5.42	5.16	5.43	15.51	11.82	9.27	9.24
50	10.26	9.72	8.41	8.00	5.97	5.67	3.49	4.93	15.15	11.96	7.11	7.34
75	9.61	9.58	9.89	9.71	6.81	5.79	4.55	3.96	13.66	11.80	12.32	11.58
100	9.48	9.54	12.26	12.30	5.87	5.99	4.47	4.54	14.15	11.79	12.31	11.50
125	9.89	9.65	12.37	11.88	5.10	5.54	6.69	6.97	14.75	12.00	13.72	14.48
150	8.58	9.81	10.25	9.71	5.28	5.64	6.64	6.77	16.25	12.05	13.50	13.13
175	11.34	9.96	7.33	7.31	5.03	5.45	5.72	6.31	16.27	12.16	12.55	12.46
200	10.45	10.06	8.54	8.91	5.33	5.37	4.95	5.23	16.63	12.11	10.21	10.01
225	10.97	10.01	8.96	8.71	5.40	5.30	5.16	5.31	15.34	12.30	11.48	11.56
250	11.15	9.85	12.05	11.57	5.34	5.40	4.75	5.27	16.26	12.08	11.29	11.51
$\bar{P}$	10.10	9.12	10.11	9.11	5.54	5.10	5.40	5.20	15.23	11.9	13.29	13.20

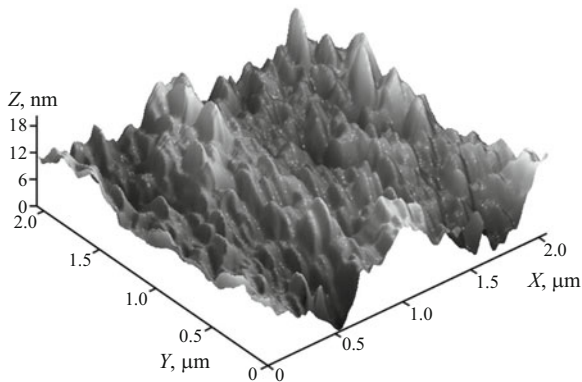


Fig. 2. 3D image of sample No. 1 (see Table 1).

profile  $R_q$  in sections along the  $X$  and  $Y$  axes differs from sample No. 1 by 5.8% for sample No. 2 and 10.9% for sample No. 3. Thus, the elementary filaments can be assumed to have the same roughness along the entire surface studied. Profiles along the  $X$  axis (line 125) and the  $Y$  axis (line 125) are presented in Fig. 1 and 3D images of sample No. 1 are displayed in Fig. 2.

When two bodies, for example, standard terminal measures (Johansson gauges), come into contact with one another molecular interaction forces cause them to stick to one another. The force required to move the gauges is at least 29.4 N [7]. The parameter  $R_z$  for the surface of a gauge is 0.063  $\mu\text{m}$ , which is 4 times greater than for elementary aluminum oxide filaments.

## CONCLUSIONS

For the surface of elementary aluminum oxide filaments the parameter  $R_z$  ranges from 0.015 to 0.0055  $\mu\text{m}$ .

Such surface roughness can cause elementary aluminum oxide filaments to stick to filament-drawing parts due to intermolecular interaction forces.

To prevent elementary aluminum oxide filaments from sticking the roughness of the filament-drawing parts must be prescribed on the basis of the roughness parameter ( $R_z = 0.32 \mu\text{m}$ ) in order for minimize the intermolecular interaction force acting between the contact surfaces.

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